

1 2 3 4 5 6

Foundations for
21st CENTURY SOCIETYEDUCATION, TRAINING,
TECHNOLOGIES, OPPORTUNITIES

Information and communication technology are having a profound effect on the way of life of people in many different cultures throughout the world. No other technology in the past has spread so rapidly and with such transforming effect. ... The transformation of societies around the globe is just beginning.

John H. Marburger III, Director of OSTP, March 2003

Innovation emerges in many forms and across all walks of life, supported by access to education, rich sources of information and ideas, and enabling technologies. The following examples suggest the breadth of this diversity.

A man with a plan

In the 1990s, a North Dakota farmer had an idea about how to help fellow farmers in his region cost-effectively improve the productivity of their land. With technical support from NASA, Montana State University, and the University of Minnesota, he created Agri ImaGIS, the first Web-enabled provider of satellite remote-sensing imagery and analysis software for precision agriculture across the U.S. and Canada. Clients log on to www.SATshot.com, where they download the free AIsatshot Viewer, based on NASA imaging software customized by the farmer and university colleagues for the agricultural application. Through partnerships with major satellite companies, the Agri ImaGIS site lets users select the exact coordinates of the near-infrared imagery they wish to purchase, download the package, then apply the software to mine the images for information, pinpointing areas of high or low productivity indicated by vegetation density and vigor, soil condition, and moisture levels. A tool called Map ImaGIS enables users to build base maps of their fields and boundary lines, which they can overlay with zone-management information such as variable watering, seeding, and fertilization metrics.

Diagnostic alert

At the University of Pennsylvania Medical School, physicians treating critically ill patients on ventilators who are at high risk of pneumonia have tested a handheld "acoustic nose" sensor array as an early-warning device for detecting the disease. Traditional diagnostic X-ray and bacterial culture methods can take several days. The "nose," a technology developed by researchers at the NSF-supported Center for Neuromorphic Systems

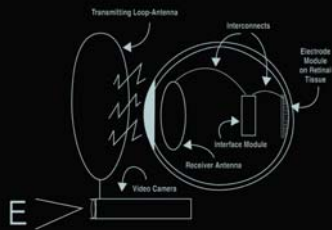
Engineering at the California Institute of Technology, clearly distinguished between patients who were infected and those who were not. Now being commercialized by Cyranose Sciences, Inc. of Pasadena, the "Cyranose" sensor array of carbon-black/polymer composites, which can be tailored to detect any type of chemical vapor, interacted with molecules in patients' exhaled breath to produce a unique electrical response displayed as a dot pattern on a computer screen. Rather than prescribing antibiotic treatments to all at-risk patients as a precaution, doctors could give antibiotics only to those signaling infection while awaiting confirmation from the more time-consuming tests, said the doctor who directed the study.

Life-saving IT network

In 2002, 171 Americans were rescued in personal aircraft and marine emergencies through an IT-based international search-and-rescue alert network co-supported by NOAA, the Coast Guard, the Air Force, and NASA. The Cold War-era program, started in 1982 by the U.S., Canada, France, and Russia, now includes 36 countries and operates around the clock, relaying radio-beacon distress signals picked up by U.S. and Russian satellites and a network of ground computer stations to a central facility for location analysis and on to the nearest rescue teams. All told, the COSPAS-SARSAT system (see page 54 for acronym details) has rescued some 14,500 people worldwide, including 4,500 Americans. Following a request by NOAA to the Federal Communications Commission, as of July 1, 2003, outdoor adventurers anywhere in the continental U.S. are also authorized to carry 406-megahertz personal locator beacons (PLBs). Unlike personal aircraft and vessels, which are required to carry such equipment, citizens who want COSPAS-SARSAT protection on wilderness trips are urged to register their PLBs with NOAA to speed rescue operations if they are needed.

A father's software discovery

An 11-year-old New York girl named Jen, confined to her home by spinal muscular atrophy, a severe form of muscular dystrophy, now uses the family computer to communicate with friends, surf the Web, and connect to school lessons because her father came across some free software developed by DARPA- and NSF-supported



a) NASA hyperspectral imaging technologies capture fine-grained information about surface features and vegetation. Scientific farming methods now incorporate imaging to regulate cultivation and improve yields.

b) Funded by DOE/SC, a public-private collaborative team is developing tiny MEMS technologies to restore vision. Eye diseases such as macular degeneration damage the rods and cones that convert light into electrical messages to the brain. **c)** In prototype, a video camera, which could be attached to glasses, transmits signals via loop antenna to MEMS devices inside the eye that stimulate retinal nerves.

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a) Students of researcher Terry Winograd (second from left) test capabilities of interactive workplace called "iRoom" in NSF-funded project at Stanford University to investigate the future roles of advanced technologies in collaborative work.



b) NSF's QuarkNet initiative with DOE brings high-school physics teachers and students to Fermi National Accelerator Laboratory (Fermilab). Last summer, Fermi scientists helped teachers build a cosmic ray detector.



c) NASA's new braille book about astronomy was evaluated by students at the Colorado School for the Blind.
d) Schematic shows operation of NOAA COSPAS-SARSAT international search-and-rescue network, which has saved thousands of lives.



e) NASA researchers work with Stanford Medical School cardiac specialists to apply agency fluid-dynamics modeling technologies to create innovative surgical planning tools that enable physicians to view and analyze patient blood flows and blockages.

researchers at Carnegie Mellon University. The two pieces of software, designed as part of a project looking at new uses for personal digital assistants (PDAs) in conjunction with desktop computers, are posted on the Web for any interested parties to "beta test." One turns a PDA into a remote keyboard and mouse; the other enables the user to create shortcut buttons on the PDA to automate computer processes. Jen, who has good fine motor control, finds the PDA's pencil stylus and touch-screen capabilities easy to use. As a result of her father's serendipitous discovery, the CMU team is working on ways to make the technology even more helpful to people with physical limitations.

Lights that talk

At Boston's Spaulding Rehabilitation Hospital, researchers funded by NIH and NSF have demonstrated a technology that uses the flickering of ordinary fluorescent lighting to transmit information to PDAs with photocells carried by patients, alerting them to appointments, room locations, and other useful in-patient details. The invention, which enabled even patients with traumatic brain injuries to navigate autonomously, won a 2002 R&D 100 Award and is being marketed by Talking Lights, LLC of Boston.

Next-generation microprocessors

A research team at DOE laboratories has transferred to the chip industry a microprocessor fabrication technology that is considered the next generation in chip-making, capable of producing processors tens of times faster than today's and memory chips with 40 times the storage capacity. The new lithographic technology uses extreme ultraviolet light (EUVL), which has 10 times shorter wavelengths than plain ultraviolet light (UVL). EUVL can etch a far greater number of features on each chip than is possible with current UVL techniques. The industry consortium that will further refine the prototype under a cooperative research and development agreement is headed by Intel and includes Advanced Micro Devices, IBM, Infineon, Micron Technologies, and Motorola. In February 2003, the DOE team was awarded the laboratories' Excellence in Technology Transfer award for its accomplishment.

f) High-school students assemble an electronic logic board at Fermilab.

E-gov: Streamlining services for citizens

Across the Federal government, new structures to improve citizen services and streamline operations are arising today from the foundations of IT R&D. Under the Administration's E-Government Strategy, agencies are moving rapidly toward two ambitious goals: quick, easy, and secure online access for citizens to government services and information, and a radical reduction in internally duplicative record-keeping, transactional, and information-processing systems through coordinated development of IT standards and procedures. (See <http://www.egov.gov/>.)

In April 2003, for example, DoD and the Department of Health and Human Services announced that they would adopt the framework of the highly regarded Veterans Administration (VA) electronic health-records system as a key step toward a secure national health information infrastructure. The VistA system (Veterans Health Information Systems and Technology Architecture), with its Enterprise Single Sign-On developed by NIST for the VA, is considered a leading example of a patient-centric, secure health-records infrastructure that improves care and reduces paperwork.

E-gov projects are also working toward IT-based simplification of Federal procurement, grant-making, and benefits systems. The NITRD Program is supporting E-gov technical activities to ensure universal citizen accessibility to services and to build state and local government and private-sector partnerships around the program's goals. In addition, NSF's Digital Government program supports a variety of technical R&D efforts to develop new technologies that expand public access to government services at all levels (<http://www.digggov.org/>).

In a grassroots collaborative project, digital archivists from NITRD agencies and others have created a highly visible symbol for a more user-oriented government – a new Web portal called [science.gov](http://www.science.gov) that organizes in one place, by category and alphabetically, links to the national treasure of scientific and technical information in the online archives of 10 Federal science agencies (<http://www.science.gov>). Other FY 2003 E-gov developments include a free online Federal tax-filing system, used by several million people in its first season, and a Web portal called [regulations.gov](http://www.regulations.gov), through which citizens can access the texts of proposed rules and

submit comments (<http://www.regulations.gov>).

NITRD support for human development

When minds can expand, new ideas – and inventions – flourish. For that reason, one ongoing focus of NITRD research is technologies to help all people enhance their individual capacities and skills. Assistive technologies and devices developed from NITRD-funded research in robotics, speech recognition, voice activation, multimodal interfaces, and wireless remote-control systems are making it possible for people of all ages with disabilities to participate more fully and independently in society.

NITRD research investments play a direct human-capital role in the national interest, underwriting the advanced education and training of tomorrow's top-level U.S. technological workforce and supporting the work of today's IT research leaders. NITRD agencies also support the Nation's main training programs to expand IT talent pools in such strategic fields as bioinformatics, cybersecurity, and advanced scientific computing.

The NITRD agencies actively champion innovation in science, mathematics, engineering, and technology education, encouraging use of their online archives for educational purposes and providing special Web sites with learning activities for children and young adults. NSF, unique among the agencies in its broad mission to advance U.S. research and education across the sciences, supports fundamental investigations of human cognitive development and innovative IT applications for education and training at every level. NASA's Learning Technologies Project develops advanced multimedia curricula for teachers to use to engage students in grades K-14 in the excitement of Earth and space sciences.

An emerging area of NITRD research sponsored by NSF – interdisciplinary studies of the social, economic, and workforce implications of IT – is developing baseline empirical findings and new knowledge that will help policymakers and citizens better evaluate and make informed decisions about IT applications in 21st century society. This work is exploring such topics as effects of new information technologies in work, education, commercial, and research environments; barriers to IT careers for women and minorities; intellectual property and information privacy issues; citizen participation in the digital society; and human values in technology design.